INDEPENDENT SCIENTIFIC PEER REVIEW OF PERFORMANCE MEASURES FOR DELTA PLAN ECOSYSTEM AMENDMENT

Performance Measure 4.6
Doubling Goal for Central Valley Chinook Salmon Natural Production

Performance Measure 4.13
Barriers to Migratory Fish Passage

John G. Williams

Petrolia, CA

jgwill@frontiernet.net

Dec. 2019

This is my review of Performance Measure 4.6, Doubling Goal for Central Valley Chinook Salmon Natural Production, and Performance Measure 4.13, Barriers to Migratory Fish Passage.

Charge to the reviewers:

The Delta Stewardship Council is amending Chapter 4 of the Delta Plan, which includes performance measures, and has arranged for expert review of the draft performance measures. According to the charge given to reviewers, "The performance measures must include "quantitative or other measureable assessments of the status and trends" of the "health of the Delta's estuary and wetland ecosystem for supporting viable populations of aquatic and terrestrial species, habitats, and processes, including viable populations of Delta fisheries and other aquatic organisms,""

The reviewers are specifically charged as follows:

> The reviewer will assess whether the respective proposed performance measures include quantitative metrics and measurable targets, are based on best available scientific information, and provide appropriate and informative evaluations of progress toward the attainment of the proposed Ecosystem Amendment goals and strategies and the coequal goal of protecting, restoring, and enhancing the Delta ecosystem. The goal of this independent scientific peer review process is to inform the development of a set of performance measures based on the best available scientific information so that the Council can evaluate the effectiveness of the Delta Plan in a quantitative and measurable way.

Short Answers:

The Delta Stewardship Council staff has provided specific questions to guide the review, which I answer below, but the answers to the broader questions in the charge are:

- The proposed performance measures do include quantitative metrics and measurable targets;
- The proposed performance measures are not based on the best available scientific information;
- The proposed performance measures do not provide useful measures of the "health of the Delta's estuary and wetland ecosystem for supporting viable populations of aquatic and terrestrial species, habitats, and processes, including viable populations of Delta fisheries and other aquatic organisms," This is because the measures respond to legal or regulatory rather than scientific concerns.

Context for Assessing the Performance Measures:

The answers to the specific questions provided by staff require context, some of which is provided by the supplemental material provided with the charge and the questions. What I see as salient points are summarized here.

The legislative context:

Two sections of the California Water Code provide the legislative context for the performance measures under review. Water Code section 85302(b) states that “The geographic scope of the ecosystem restoration projects and programs identified in the Delta Plan shall be the Delta, except that the Delta Plan may include recommended ecosystem projects outside of the Delta that will contribute to achievement of the coequal goals.” Water Code section 85302(c) provides that “The Delta Plan shall include measures that promote all of the following characteristics of a healthy Delta ecosystem” and then lists five characteristics. The most relevant for this review is the fifth: “Conditions conducive to meeting or exceeding the goals in existing species recovery plans and state and federal goals with respect to doubling salmon populations.” These sections explain performance measures that otherwise have little to do with the Delta.

The federal doubling goal is embodied in the Central Project Improvement Act (CVPIA). In the CVPIA, Congress mandated, with some qualifications, “… all reasonable efforts to ensure that, by the year 2002, natural production of anadromous fish in Central Valley rivers and streams will be sustainable, on a long-term basis, at levels not less than twice the average levels attained during the period of 1967-1991...” Natural production is defined in CVPIA section 3403(h): “The term ‘natural production’ means fish produced to adulthood without direct human intervention in the spawning, rearing, or migration processes;” The CVPIA does not quantify natural production during the base period. Instead, this was done administratively.

Adaptive Management

Charge Question 7 concerns adaptive management, so it seems convenient to describe adaptive management at the outset. I will re-use some text from Ch. 6 in Williams et al. (2019) to do this. Particularly relevant language is italicized.

> Adaptive management has been a popular recommendation for environmental flow assessment since Castleberry et al. (1996). According to Poff et al. (2009:164–165) “Ideally, the ELOHA framework should be used to set initial flow standards that can be updated as more information is collected in an adaptive cycle that continuously engages water managers, scientists and stakeholders to ‘fine tune’ regional environmental flow standards.” Linnansaari et al. (2012:v) wrote that: “Regardless of the type of framework to be established, it is fundamental that the

established environmental flow standards are preceded and followed by a controlled monitoring program and the possibility to refine the environmental flow regime standards by adaptive management in an iterative process."

Adaptive management has nevertheless been difficult to apply effectively. Probably the greatest obstacle is mental; good adaptive management requires a more scientific mindset than is common among regulators, agency managers, stakeholder advocates, and even many fish biologists. In our experience, they tend to focus more on reaching decisions than on learning. However, an exemplary application in Australia is described below.

A conceptual model from Healey et al. (2008) provides a good overview of adaptive management, which is presented as a cyclical process in which even the understanding of the problem and the goals of management can change in light of new information (figure 1). *Performance criteria, to keep the assessments from becoming post–hoc rationalizations, are an important but uncommon element.*

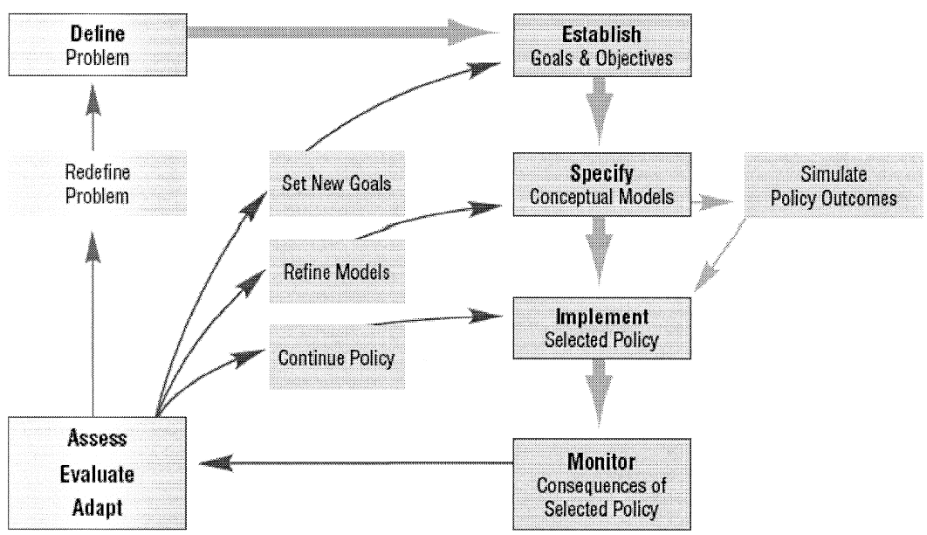

Figure 1. Conceptual model of the adaptive management cycle. Note that "policy" as used here may include taking some action. Source: Figure 6.1 in Healey et al. (2008).

It is common to distinguish active adaptive management, or actual management experiments, from passive adaptive management, which is essentially observational (e.g., Gregory et al. 2006). An example of active adaptive management applied to environmental flows was described by Failing et al. (2004) and Gregory et al. (2006), and also in Chapter 7. Briefly, a dam on the Bridge River, British Columbia had existed with no flow releases for about forty years, although inflow from tributaries below the dam provided some flow to most of the study reach. The proposed experiment consisted of releases at four rates of discharge for several years each, with an active monitoring program. Unfortunately, only two of the treatments were implemented, so learning was limited (Bradford et al. 2011).

Litigation regarding environmental flows in the lower American River in California produced an example of passive adaptive management (Castleberry et al. 1996). The court decision set did not mandate flow releases from a dam, but did prohibit diversions from the reservoir by a municipal utility district unless interim flow standards were met below the dam. The judge recognized the uncertainty regarding the flows needed to achieve the intended level of environmental protection, and so ordered the parties to cooperate in studies to clarify what the flow standards should be. One of us (JGW) was appointed to supervise these studies.

A major issue in the controversy concerned rearing flows for Chinook salmon. One side argued that lower flows in the spring would result in faster growth of juvenile Chinook, while the other argued that lower flows would result in slower growth. Water temperature in the spring rearing season varies inversely with flow, so the argument was really about the relation between water temperature and growth, which depends strongly on the amount of food available. With enough food, juvenile Chinook grow rapidly at temperatures that would be harmful if less food were available. Because there is considerable variation in spring flow and temperature in the lower American River regardless of management, the relation between temperature and growth could be clarified by sampling juvenile Chinook and determining their growth rates by otolith microstructure analysis. Although the monitoring program ended prematurely, the preliminary results strongly suggested that growth was faster at lower flows (Williams 2001).

Active adaptive management is difficult because: (1) it is politically difficult to arrange; (2) ecosystem responses take time, so the experiments do as well; (3) other and uncontrolled factors also affect the system of interest, subjecting flow experiments to unexpected problems. A 12–year adaptive management program on the San Joaquin River in California failed to give clear results (Dauble et al. 2010), probably because of such confounding factors. Although learning takes longer with passive adaptive management, it seems much easier to do and effective learning is still possible provided there is enough variation in the key driving variables, as in the American River example just discussed, and the monitoring program is well designed. In these cases, passive adaptive management seems the preferred approach. This does not preclude taking a scientific approach; sciences such as geology are primarily observational. Rather, whether the adaptive management is active or passive, the challenge is to do it well. *The selection of good response measures can be critical; in the American River case just discussed, learning depended on measuring attributes of individuals (growth rates from otoliths), rather than just population attributes such as abundance. Individual–based metrics tend to be more informative (Osenberg et al. 1994).*

Performance Measure 4.6: Doubling Goal for Central Valley Chinook Salmon Natural Production.

Achieve the state and federal doubling goal for Central Valley Chinook salmon natural production against the baseline for the period of 1967-1991.

The performance measure comes with an expectation, a metric, a baseline, and a target.

The expectation is: "The average annual production of all Central Valley Chinook salmon runs is 990,000 by 2065, which is double the 1967-1991 baseline.

The metric is: " Fifteen-year rolling annual average natural production of all Central Valley Chinook salmon runs (fall, late fall, spring, and winter). This metric is measured annually."

The baseline is: "Set by the Central Valley Project Improvement Act (CVPIA), the baseline is the 1967-1991 Chinook salmon natural production annual average of 497,054 for all Central Valley runs."

The targets are: "1) The 15-year rolling annual average of natural production for all Central Valley Chinook salmon runs is 990,000 by 2065, nearly doubling the baseline of 497,054.

2) The slope of the 15-year rolling annual average of natural production for all Central Valley Chinook salmon runs is greater than zero (i.e., positive) for the period of 2035-2065."

Charge Questions:

Question 1
How clear and thorough are the performance measure's metric, baseline, and target? What, if any, additional information is needed?

The measure's metric and baseline, and targets are clearly stated, and, in a superficial sense, provide the information needed for the performance measure. In a deeper sense, however, the metric, baseline, and targets implicitly embody the misleading notion that all naturally produced Chinook are equal, as discussed in the answer to Question 2. Moreover, it is questionable whether Target 1 "nearly" meets the CVPIA doubling goal. It matters that the doubling goal refers to "levels," as discussed by Newman and Hanken (2004:23):

> First, the CVPIA itself and Appendix A of the Final Restoration Plan for the Anadromous Fish Restoration Program (USFWS 2001) both seem to call for doubling to be achieved on river or stream-specific bases. Section 3406 (b)(1) of Public Law 102-575 states, in part: "... natural production of anadromous fish in

Central Valley rivers and streams will be sustainable, on a long term basis, at levels not less than twice the average levels attained during the period of 1967-1991...” And, at Appendix A-15 of the Final Restoration Plan, it is stated that: “Numeric restoration goals for Chinook salmon in each stream will be calculated as at least double the average of PX,N,XX for each of the years during the baseline period.” Together, these statements leave little doubt that it would not be enough to double overall natural production of, say, fall-run Chinook salmon in Central Valley streams. Instead, production is to be doubled, on a sustainable basis, in individual tributary streams.

Thus, lumping all runs and streams together in a metric seems problematic with respect to the doubling goal, besides making no sense biologically.

Question 2

How clear is the basis for selection of the performance measure? How complete are the scientific rationale, the justification, and the supporting references for the selection?

The basis for the selection of the performance measure is clear enough; it responds to Water Code section 85302(c)(5). Unfortunately, the performance measure is based on an act of Congress, not scientific information, and has no scientific rationale. The doubling goal established by the CVPIA was based on twice the average levels of natural production during the period of 1967-1991. However, the levels of natural production for 1967-1991 are poorly known, for two main reasons:

1) Except for the Sacramento River above the Red Bluff Diversion Dam for 1967-86,[1] the number of naturally spawning Chinook in Central Valley rivers and streams was not well known. The shortcomings of early escapement estimates were described by Fry (1961), and as far as I could ever learn, improvements came slowly. From a management perspective, the total number of fish returning to spawn (the escapement) was monitored mainly in order to determine whether the escapement goal for Sacramento River Fall Chinook set by the Pacific Fisheries Management Council (PFMC) was being met. Escapement was normally well above the lower end of the range, so accurate estimates were not needed. Problems with the estimates are discussed in Williams (2006:271):

> Most Central Valley salmon can reach their spawning grounds without passing a dam, so estimates of adult returns cannot be based on ladder counts. Instead, estimates are usually based on mark-recapture approaches applied to carcasses: spawning reaches are surveyed repeatedly, unmarked carcasses are tagged and tallied, and “recaptures”

[1] Migrating fish had to pass a ladder on the Red Bluff Diversion Dam during this period, and could be counted.

of previously marked carcasses are also tallied. Estimates of adult returns are then developed, usually using an estimator described by Schaefer (1951) or (and increasingly) by Seber (1982), but sometimes also using a modified Petersen formula. These estimators entail assumptions—for example that all carcasses are equally likely to be found, that are more or less seriously violated in different streams or at different times—and they can give significantly different estimates. For the American River in 1995, for example, the Schaefer and Jolly-Seber estimates were 70,096 and 42,973, respectively (Williams 2001a). Compared to weir counts on the Stanislaus River, Jolly-Seber estimates were 18% higher and 24% lower in 2003 and 2004 respectively, while Schaefer estimates were 37% higher and 9% lower. Unfortunately, it has not been standard practice to report confidence intervals for the estimates, although programs are available that can generate them, at least for the Jolly-Seber method.

2) The percentages of naturally spawning fish that were naturally produced was poorly known for fall Chinook and spring Chinook in the Feather River, which are produced in large numbers by hatcheries. No effort was made to distinguish naturally produced fish in surveys of catch or escapement, probably because the PFMC did not make that distinction. When The PFMC was developing escapement goals in the late 1970s - early 1980s, California Department of Fish and Game (CDFG) recommended that separate escapement goals be set for hatchery and naturally produced fish, the PFMC declined to do so, on the grounds that "The separation of hatchery and natural fish … is artificial" (Williams 2006:240). The result was gently described by Newman and Hankin (2004:25): "Because there are few or no existing estimates of freshwater catches and hatchery fish percentages for individual streams, interagency biologists agreed upon reasonable guesses of these quantities that allowed generation of the complete time series of stream-specific estimates of natural production that seem required under the CVPIA doubling goals mandate."

As a separate problem, the doubling goal implicitly treats naturally produced fish as interchangeable units. This is misleading because the Central Valley supports four distinct runs of Chinook, and Chinook return to Central Valley rivers to spawn (a good definition of maturity) at ages now ranging mainly from 2 to occasionally 5 years, although formerly 5 year-olds were common and there were some 6 year-olds (Williams 2006, Ch. 13; Figure 1). Length increases with age, and weight, which matters most to fishermen, increases exponentially with length. Biologically, it makes sense to assess the value of returning fish in terms of their reproductive potential, which also increases with size. Only females lay eggs, and fecundity increases with length (Williams 2006, Ch. 6). Larger fish can spawn in coarser gravel than smaller fish (Kondolf and Wolman 1993), so all else equal, there will be more spawning habitat for a Chinook population with a broader size distribution. Hence, large females are doubly valuable to a population.

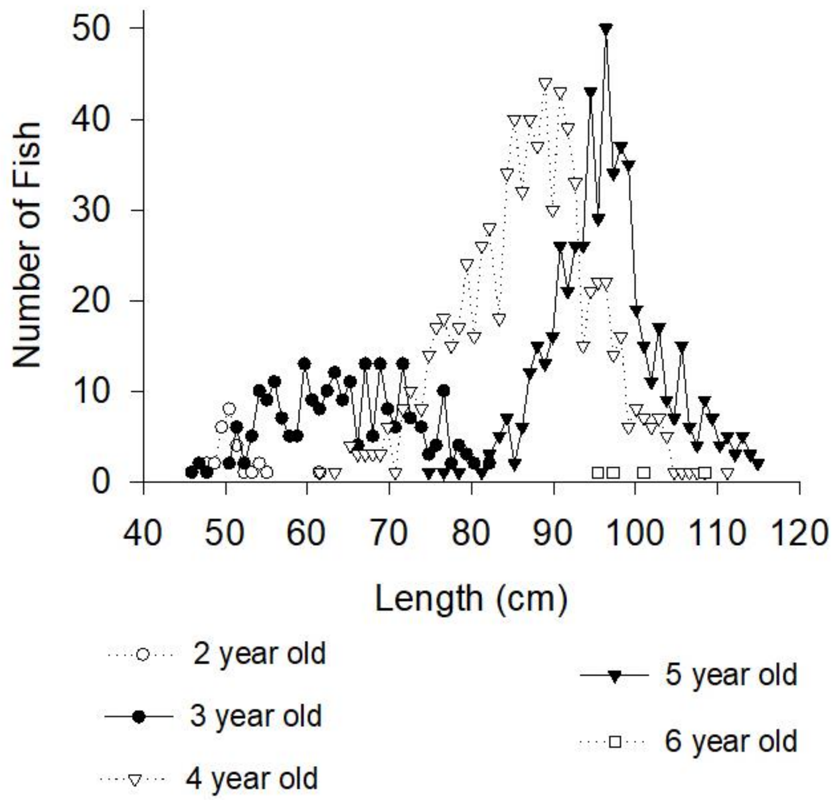

Figure 2. Size distribution of adult Chinook taken in the Delta gill net fishery in 1919 and 1921. Lengths are fork lengths. Data from Clark (1928). The age distribution has been reduced by about one year since these data were collected, presumably by the mixed-age ocean fishery. Note that the nets were size-selective, so especially 2 year-olds and small 3 year-olds are underrepresented in this sample.

The differences among the runs of Chinook matter for management of the Delta, because the different runs generally follow different juvenile life history patterns and use the Delta in different ways and at different times (Williams 2012). In particular, a large but poorly known fraction of juvenile fall Chinook migrate to the Delta as fry and rear there (Williams 2012). According to Dahm et al. (2018:102):

> Diversity of juvenile life history types among Chinook salmon enables the species to more fully utilize available habitats, potentially increasing capacity. Diversity also reduces the risk of severe reductions in abundance due to catastrophic environmental conditions in specific habitats. Percentages of fry (~<55 mm), parr (~56-75 mm), and yearling smolts (>75 mm) captured in traps can be

documented (see Miller et al. 2010) and compared over time with restoration actions (e.g., creation of shallow rearing habitats occupied by fry and parr in the Delta). Essentially all fry migrants are natural origin because hatcheries rarely release juveniles of that small size. Contribution of fry and parr to adult returns can be evaluated by assessing the frequency of these life history types in adult Chinook salmon, as described by Miller et al. (2010), who documented unexpectedly large contributions of fry migrants (20%) in adult fall Chinook salmon by analyzing otoliths.

Twenty percent is a serious underestimate for naturally produced fish, because Miller et al. did not distinguish naturally produced from hatchery Sacramento River fall Chinook fish (J. Miller, pers. comm., 2011), so an unknown percentage of their sample was hatchery fish. If the sample was 75% hatchery fish, as seems plausible (Palmer-Zwahlen et al. 2019 estimated that 77.6% of fall Chinook returning to the Central Valley in 2015 were hatchery fish), then **80%** of naturally produced adult Central Valley fall Chinook in Miller's sample were fry migrants. In other words, if the sample was anything like representative, the Delta is critical rearing habitat for juvenile fall Chinook.

Juveniles from other runs tend to enter the Delta as older and larger fish, and to stay there variable amounts of time (Williams 2012). Within the Delta, the smaller fish presumably make more use of tidal habitats. As a result, restoring tidal habitat can be expected to increase the production of fall Chinook, but not, say, Butte Creek spring Chinook, which seem to migrate quickly through the Delta. The upshot is that a draft performance measure based on the combined natural production of all runs of Chinook will not help "… the Council evaluate the effectiveness of the Delta Plan in a quantitative and measurable way."

Question 3
How clear and complete is the scientific basis for setting the targets? How complete is the consideration of key scientific references, available data, and existing monitoring capabilities?

There are two targets:

1) The 15-year rolling annual average of natural production for all Central Valley Chinook salmon runs is 990,000 by 2065, nearly doubling the baseline of 497,054.
2) The slope of the 15-year rolling annual average of natural production for all Central Valley Chinook salmon runs is greater than zero (i.e., positive) for the period of 2035-2065.

The scientific basis for the 990,000 target is feeble, as described above.

The second target is explained as follows, in the section of the data sheet labeled "Basis for selection":

> In 2018, the State Water Resources Control Board (SWRCB) charged an Independent Scientific Advisory Panel with developing methods for formulating biological goals for the Bay-Delta Water Quality Control Plan. The Advisory Panel concluded that the baseline for the doubling goal overestimated the natural-origin population (by underestimating hatchery-origin Chinook salmon in total returns) and therefore the doubling goal for natural-origin salmon might also be overestimated (Dahm et al. 2019). Because of the uncertainty in the baseline calculations, an increase in the natural production (positive trend) may provide a better goal, rather than the goal to double the natural production (Dahm et al. 2019).

I agree that natural production probably was overestimated, so that positive population trends would be a better goal, but I cannot see any scientific reason for a target that cannot be calculated until 2035. Similarly, I do not a scientific basis for a target that lumps the different runs of Chinook together. Finally, although I understand the logic behind smoothing the population trace, I think that a 15 year running average would respond too slowly to management actions to provide useful feedback. I discuss this again in the answer to Question 7.

There are a great many relevant scientific references and data, including descriptions to possible approaches to monitoring. Only a few are cited. Naturally, I am partial to my own articles (Williams 2016; 2009; 2012), but there are other good ones, as well.

Question 4
How achievable are the targets relative to the stated time scales?

Given global warming and the continuing mixing of hatchery and naturally produced fish on the spawning grounds, and the consequent loss of fitness for natural production, the target of a running average of 990,000 naturally produced fish by 2065 does not seem achievable. Without knowing the natural production for 2020-2035, one can only speculate whether a continuing increase in the running average of after 2035 is achievable.

Question 5
How well were scientific uncertainties (both outside and within management control) incorporated in the development of the targets and in the assessment of progress towards the targets?

It is not clear how the uncertainty regarding the percentage of naturally produced fish in the harvest and escapement will be incorporated in the target.

Question 6
Are the identified data sources complete and appropriate to support robust assessment of the performance measure?

The identified data sources are not complete or appropriate, because they do not provide information on the percentage of hatchery fish in the escapement or captured in the fishery. Unfortunately, not all hatchery fish are marked. Supposedly, hatcheries are marking 25% of hatchery fish in a "constant fractional marking" program, but in practice the fraction of marked fish is variable, so estimating the fraction of hatchery fish is complicated, and requires information obtained by reading coded wire tags. This makes it impossible for the crews conducting escapement surveys to identify hatchery fish, and information on the percentage of hatchery fish comes out years later. For example, Palmer-Zwahlen et al. (2019) give estimates for 2014; estimates for 2015 are forthcoming. If all hatchery fish were marked, as they should be, this would not be a problem.

ChinookProd, one of the main data sources listed, is problematic. Consider Figure 1 in the datasheet. This is taken from a U.S. Fish and Wildlife Service (USFWS) website, where it is labeled as a draft dated 2016. It claims to show natural production through 2015. However, estimates of the percentage of hatchery fish in the 2015 harvest and escapement are still not published, as just noted, so it is unclear to me how natural production for 2015 could have been calculated in 2016.

Question 7
How well are adaptive management and alternative actions considered in performance assessments and reporting?

I do not see that adaptive management or alternative actions are considered at all. This is understandable, because the performance measure is not based on scientific understanding that might be clarified by monitoring implementation of the measure. Considering the development of adaptive management may help to explain this. Adaptive management was first proposed by Walters and Hilborn (1976) for setting escapement targets for salmon populations, or, more specifically, for estimating the parameters of stock-recruitment models used to set the targets. If harvest were successfully regulated to meet the target indicated by the stock-recruitment model, then there would not be enough variation in escapement for managers to improve the estimates of the parameters. However, by experimentally increasing or decreasing harvest from the estimated target, more informative escapement data could be obtained.

The concept of adaptive management has since been broadened and developed, as described in the introductory material above, but the basic idea remains that there must be some hypothesis or conceptual model to be clarified by monitoring the response of the variable in question to management, or to natural variation in a driving variable of interest, and there must be the intention to modify management in light of the clarification.

Regarding the doubling goal, Newman and Hankin (2004) discussed using state-space models for assessing progress toward and achievement of the doubling goal. NOAA Fisheries now supports a package for state-space modeling of populations called MARSS (Holmes et al. 2018) that might be used, although statistical expertise would still be required. Moreover, Chinook populations depend on many other factors besides conditions in the Delta. It seems more reasonable for the Delta Stewardship Council to leave worrying about the doubling goal *per se* to others, and to focus instead on "Conditions [in the Delta] conducive to meeting or exceeding the goals in existing species recovery plans." There are various ways this could be done, for example:

1) Use the Chinook life cycle model under development by NOAA Fisheries to quantify the link between conditions in the Delta and Chinook populations by run, taking account of conditions in the other habitats used by Chinook. For example, for fall Chinook, transitions 4 and 9 in Figure 4 from Hendrix et al. (2017) could be used to quantify conditions for fry migrants to the Delta. This approach could take advantage of the use of the model by others, in which case the Delta Stewardship Council staff would not need to run it.

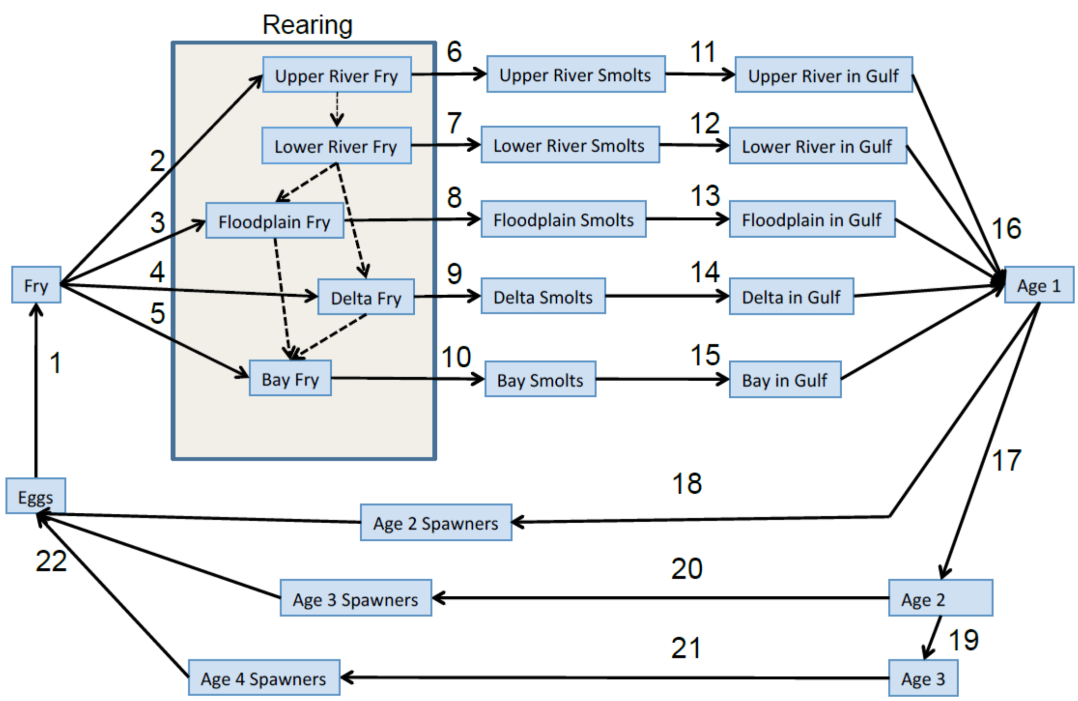

Figure 3. Central Valley Chinook transition stages. Each number represents a transition equation through which we can compute the survival probability of Chinook salmon moving from one life stage in a particular geographic area to another life state in another geographic area.

2) Use indirect measures such as the area of tidal habitat in the Delta that is available for juvenile fall Chinook. This matters, as noted by Dahm et al.

2019:43): “The need to include measurements in these shallow water zones rests on the substantial use of these areas by smaller salmon that are more likely to be of natural origin (Miller et al. 2010, Chapter 3).”

3) Use physiological variables such as recent growth rates measured by RNA/DNA ratios in tissue samples collected from juvenile Chinook that are using tidal habitat in the Delta. Ch. 15 in Williams (2006) discusses such variables and provides an entry into the relevant literature.

As a final comment, the performance measure in the 2018 amended Appendix E at p. E-9 strikes me as more informative than the proposed measure, since it calls for monitoring the natural production of Chinook by river. Information is lost by considering only the sum.

Performance Measure 4.13: Barriers to Migratory Fish Passage:

Resolve fish passage at priority barriers and select large dams in the Sacramento-San Joaquin River watershed, and screen diversions along native, anadromous fish migration corridors within the Delta.

The performance measure comes with an expectation, a metric, a baseline, and a target.

Expectation:

Resolving priority fish migration barriers and screening Delta diversions improves fish migration, reduces fish entrainment, enhances aquatic habitat connectivity, and contributes to anadromous species recovery.

Metric:

Priority fish migration barriers and select large dams in the Sacramento-San Joaquin River watershed, and unscreened diversions along native, anadromous fish migration corridors in the Delta and Suisun Marsh. This metric will be evaluated annually.

Baseline:

Number of fish passage barriers, rim dams, and unscreened diversions listed in:

1) California Department of Fish and Wildlife (CDFW) Priority Barriers (2018).
2) Central Valley Flood Protection Program (CVFPP) Conservation Strategy (Appendix K, 2016).

Target:

1) By 2030, resolve all (100 percent) of the priority fish migration barriers (listed in CDFW 2018 Priority Barriers (2018) and CVFPP 2016 Conservation Strategy).
2) By 2050, resolve 50 percent of fish passage at rim dams in the Sacramento-San Joaquin River watershed, and screen 50 percent of unscreened diversions along native, anadromous fish migration corridors in the Delta.

This measure involves three different issues, fish screens, migration barriers in the valley, and rim dams. For clarity, I answer the charge questions for each issue separately.

Unscreened diversions:

Question 1
How clear and thorough are the performance measure's metric, baseline, and target? What, if any, additional information is needed?

The metric, baseline, and target are clear.

Question 2
How clear is the basis for selection of the performance measure? How complete are the scientific rationale, the justification, and the supporting references for the selection?

The scientific rationale for screening diversions is not clear. The datasheet gives three citations: NMFS (2009; 2011), and CDFW et al. (2014) that assume but do not justify the need to screen more diversions. The discussion of the problem in CDFW et al. (2014:104) is typical: "…screens are needed on the remaining unscreened large, medium-sized, and small diversions. Losses at these diversions continue to threaten the health of the anadromous fish populations," but it gives no citations. This reinforces the point made by Moyle and Israel (2005:2) in an article titled Untested assumptions: effectiveness of diversions for conservation of fish populations: "Fisheries agencies have historically not evaluated effectiveness of fish screens because screening seems so obviously beneficial to fish." Similarly, Poletto et al. (2015:2) note that "Despite the relatively widespread acceptance of the effectiveness of some fish protection systems by managers, empirical investigations of the efficacy of man devices are lacking."

However, there are opportunity costs associated with fish screens, since the screens can be expensive and compete for funding with other restoration efforts (Moyle and Israel 2005), and other fish-protection systems such as louvres may be more cost-effective (Poletto et al. 2015). Moreover, diversions may entrain mainly introduced species, so that even if screens dramatically reduce entrainment, the absolute numbers of species of concern that are entrained by unscreened diversions may be small (Nobriga et al. 2004). The point is that all unscreened diversions are not equally a problem, and screening may not be the best resolution for some of them, so that much remains to be learned and assessing progress toward resolving the problem efficiently requires more than simple counts of the number screened.

Question 3
How clear and complete is the scientific basis for setting the targets? How complete is the consideration of key scientific references, available data, and existing monitoring capabilities?

The scientific basis for setting the target for fish screens is not clear or complete, as discussed in the answer to Question 2. Besides the references cited there, Williams (2009:64) had the following to say:

> There are thousands of smaller diversions on Central Valley rivers and the Delta, most unscreened or poorly screened. These entrain some Chinook or steelhead, but the effects of these on salmon populations is uncertain (Moyle and Isreal 2005). A recent study in the Delta by Nobriga et al. (2004) found that large numbers of larval and postlarval fishes were entrained in an unscreened diversion, but most of these were small non-native species. Generally, smaller

> fish are more vulnerable to entrainment than larger fish, and small Chinook are in the Delta mainly during the winter and early spring when diversion rates are low. Diversions on smaller streams may take a significant fraction of the flow, even if the absolute amount is small, and these may have a greater effect on the local populations. In light of the equivocal evidence for effects on populations, Moyle and Israel (2005) recommended that public money not be spent on screens "unless the projects have a strong evaluation component to them, including intensive before and after studies."

NMFS (2009) may seem to provide support for the measure at pp. 771-772, but it is feeble:

> The Central Valley Project/State Water Project (CVP/SWP) operations Biological Assessment (BA) analyzed the impact of 123 unscreened diversions located downstream of Red Bluff Diversion Dam (RBDD) based on previous studies at unscreened diversions (Hanson 2001), and average juvenile passage from 1994 through 1999 at RBDD (Gaines and Martin 2002 op. cit. CVP/SWP operations BA). Timing and quantity of diversions was based on the monthly averages for CVP contractors with unscreened diversions from 1964 through 2003. A summary of the estimated entrainment by month is presented in table 13-5.

Table 1. Estimated monthly entrainment of juvenile salmonids for 123 unscreened diversions in the Sacramento River based on historic water usage (Project + Base supply) and fish passage estimates from 1994 to 1999 at Red Bluff Diversion Dam (summarized from Tables 11-12 through 11-16 in the CVP/SWP operations BA).

	April	**May**	**June**	**July**	**August**	**Sept.**	**Oct.**	**Total**
Average flow (cfs)	10,404	9,435	11,110	13,082	9,683	6,730	7,013	
Winter-run	4	2	0	342	3,545	3,241	308	7,442
Spring-run	439	82	3	0	0	0	14	538
O. mykiss	18	132	37	26	117	62	2	394
Fall-run	6,754	4,237	3,645	1,788	685	53	1	17,163
Late fall-run	371	285	127	196	495	117	23	1,613
Green sturgeon	0	24	36	96	43	1	0	200

However, Hanson (2001) described experimental releases of hatchery winter Chinook upstream from a large diversion from the Sacramento River near Princeton. Extrapolating those results to small diversions in the Delta is problematic. The diversions are different, and, as noted by Hanson (2001:338): "… the juvenile salmon used in these mark-recapture tests were hatchery reared and released a relatively short distance upstream of the diversion (0.55 miles) and may, therefore, not be representative of the behavioral patterns or distribution of wild salmon …"

Question 4
How achievable are the targets relative to the stated time scales?

As far as I know the fish screen target is achievable. It is simply a matter of money, or of requiring the owners of the diversions to screen them.

Question 5
How well were scientific uncertainties (both outside and within management control) incorporated in the development of the targets and in the assessment of progress towards the targets?

Scientific uncertainties are not well included, as discussed in the answer to (2), above.

Question 6
Are the identified data sources complete and appropriate to support robust assessment of the performance measure?

The sources seem appropriate, since the data come from a regulatory agency. However, from looking at the sources, it is not clear to me where the information on the diversions comes from.

Question 7
How well are adaptive management and alternative actions considered in performance assessments and reporting?

As far as I can tell, adaptive management and alternative actions are not considered at all regarding fish screens. To be adaptive, there would have to be some way for monitoring the results of the action to clarify or modify the expectation.

Passage barriers

Question 1
How clear and thorough are the performance measure's metric, baseline, and target? What, if any, additional information is needed?

The metric, baseline and target fit logically together. However, a broader view of passage barriers would consider the various levees and tide gates that keep juvenile Chinook from potential rearing habitat. As noted in the review of Performance Measure (4.6), tidal habitat is very important for fall Chinook.

Question 2
How clear is the basis for selection of the performance measure? How complete are the scientific rationale, the justification, and the supporting references for the selection?

The basis for selecting the barriers is clear in one sense but not in another. It is clear that the barriers are selected because either CDFW or California Department of Water Resources (DWR) selected them, but the criteria or scientific rationale for the selections is not clear. Clearly, the agencies used different criteria, because relatively few of the barriers listed in tables 1 and 2 in the data sheet were selected by both agencies. Moreover, according to the California Fish Passage Assessment Database (PAD) [ds69]: "The data in the PAD are a reflection of the datasets that have been found to date by PAD staff, not the actual state of fish passage in streams."

According to CDFW's 2018 priority list, "The following criteria were considered in the creation of this list: 1) high likelihood to improve migration for anadromous species; 2) availability of recent fish and habitat data; 3) willing partners and land access; 4) known political support at a local, State or national level; 5) if the site is a barrier to a federal recovery plan "Core" population; 6) if the watercourse is an eco-regional significant watershed; 7) if the Department is committed to monitoring before, during and after any barrier improvement project is undertaken; and 8) if the site is considered a keystone barrier."

How this plays out in practice is not clear. Consider for example a river with which I am very familiar. The 2011 priority list (available on PAD website) lists the Old Carmel Dam, San Clemente Dam, and Los Padres Dam on the Carmel River in Monterey County. The Old Carmel Dam and San Clemente Dam since have been removed, which increases the importance of Los Padres Dam as a barrier, since it is upstream from the other dams but below the best steelhead rearing habitat in the basin. However, Los Padres Dam has been dropped from the 2017 list, which lists only a partial barrier on the Big Sur in Monterey County.

On another matter, there is no consideration of water temperature as a barrier, which will likely become more of an issue with global warming. Past concerns about the issue are discussed in (Williams 2006:117):

> Water temperature: Hallock et al. (1970) reported that water warmer than 21°C blocks migration of Chinook into the San Joaquin River and water warmer than 19°C inhibits it. However, data from the new weir on the Stanislaus River indicate that in 2003 over 500 Chinook passed through water 21°C daily average, or warmer, in the lower San Joaquin River (SRFG 2004). The role of temperature in blocking migration should be clarified as data from this weir or others that may be installed on other tributaries accumulate. Whether migration through such warm water harms gametes should also be considered.

Question 3
How clear and complete is the scientific basis for setting the targets? How complete is the consideration of key scientific references, available data, and existing monitoring capabilities?

As noted in the answer to Question 2, the scientific basis for selecting barriers for the list is unclear, so it follows that the scientific basis for setting the targets is also unclear. Moreover, it is clear that non-scientific factors such as political support for projects figure into the selection of the targets.

Question 4
How achievable are the targets relative to the stated time scales?

Given the ordinary pace of projects and the associated paperwork, resolving all the barriers listed in tables 1 and 2 of the datasheet in eleven years seems ambitious.

Question 5
How well were scientific uncertainties (both outside and within management control) incorporated in the development of the targets and in the assessment of progress towards the targets?

It is not clear how scientific uncertainties were incorporated in the development of the targets.

Question 6
Are the identified data sources complete and appropriate to support robust assessment of the performance measure?

Yes.

Question 7
How well are adaptive management and alternative actions considered in performance assessments and reporting?

As far as I can tell, they are not. I do not see how information from monitoring progress in resolving the barriers would affect the performance measure.

Rim Dams:

Question 1
How clear and thorough are the performance measure's metric, baseline, and target? What, if any, additional information is needed?

The metric, baseline, and target are clear. They would be more meaningful if they took account of the amount and quality of potential habitat above the dams. For example, the target could be to make half of the potential habitat above the rim dams available by 2050.

Question 2
How clear is the basis for selection of the performance measure? How complete are the scientific rationale, the justification, and the supporting references for the selection?

The rationale for moving fish around the rim dams is clear and compelling, but two distinct questions remain: whether passing enough fish around a dam to sustain a population is feasible, and, if so, which dams should be prioritized? NMFS (2014) mentions rim dams only once, as follow: "Conduct a Central Valley-wide assessment of anadromous salmonid passage opportunities at large rim dams including the quality and quantity of upstream habitat, passage feasibility and logistics, and passage related costs." This seems appropriate.

Question 3

How clear and complete is the scientific basis for setting the targets? How complete is the consideration of key scientific references, available data, and existing monitoring capabilities?

Setting the target in terms of the amount and quality of habitat that would be made available seems better than setting it simply in terms of a percentage of the dams.

On a minor point, Table 3 in the data sheet lists Folsom Dam, but does not mention that Nimbus Dam, currently the barrier to upstream migration, is downstream from Folsom.

On another minor point, I am a bit confused by the discussion of Butte Creek in the section on rim dams and climate change in the data sheet, since there is no rim dam on Butte Creek. Chinook are blocked from higher elevations by a natural barrier in Butte Creek, as described in Appendix A of Williams (2006):

> Chinook habitat in Butte Creek extends only to about 300 m elevation, where a natural barrier blocks all migration by spring-run in most years, although a few pass in exceptionally wet springs. A hydropower diversion dam now blocks even steelhead about 1.4 km farther upstream, but there are more natural barriers farther upstream, and the natural limit to Chinook and steelhead passage is unknown.

Question 4

How achievable are the targets relative to the stated time scales?

Whether the target is achievable at all is questionable. There seems to be work ongoing to explore potential solutions (e.g., Clancy 2016), but whether one will be found is unclear. To provide passage for anadromous fish, ways must be found for adults to get above the dams, and for juveniles to get below them. As far as I know, there is no known way to get sufficient numbers of juveniles below the dams. Juveniles are passed over dams on the Columbia River, for example, but these are run of the river hydroelectric dams that impound relatively small reservoirs. The rim dams are storage dams that back up such large reservoirs that there is no current to guide the juveniles to collection facilities at the dam, and the water level in the reservoirs varies seasonally. Flow into the reservoirs also varies. As far as I know, no one has devised a collection system that would work in these conditions.

Question 5
How well were scientific uncertainties (both outside and within management control) incorporated in the development of the targets and in the assessment of progress towards the targets?

I do not see scientific uncertainty incorporated at all in the development of the target.

Question 6
Are the identified data sources complete and appropriate to support robust assessment of the performance measure?

The data sources are adequate.

Question 7
How well are adaptive management and alternative actions considered in performance assessments and reporting?

I do not see that adaptive management or alternative actions are considered at all, for reasons given before.

Concluding comments. It should be clear from my review that I question whether these performance measures serve a useful purpose. However, except for unscreened diversions and barriers in the Delta, they strike me as relatively harmless, since they involve projects that would not be part of the work of the Delta Stewardship Council, and other agencies will collect the data needed to assess progress toward the targets.

References:

Barnett-Johnson, R.; Grimes, C. B.; Royer, C. F., and Donohoe, C. J. 2007. Identifying the contribution of wild and hatchery Chinook salmon (Oncorhynchus tshawytscha) to the ocean fishery using otolith microstructure as natural tags. Canadian Journal of Fisheries and Aquatic Sciences: 64:1683-1692.

California Department of Fish and Wildlife, U.S. Fish and Wildlife Agency, and National Marine Fisheries Service (CDFW et al.). 2014. Ecosystem Restoration Program Conservation Strategy for Restoration of the Sacramento-San Joaquin Delta, Sacramento Valley and San Joaquin Valley Regions (p. 261).

California Department of Water Resources (DWR). 2016. Synthesis of Fish Migration Improvement Opportunities in the Central Valley Flood System. Central Valley Flood Protection Program Conservation Strategy, Appendix K.

Clancy, K. 2016. Modeling Head-of-Reservoir Conditions at Shasta Lake, California to Evaluate Downstream Juvenile Fish Passage. Ms thesis University of Nevada, Reno.

Clark, GH. 1928. Sacramento- San Joaquin salmon (Oncorhynchus tschawytscha) fishery of California. Fish Bulletin 17:1-73.

Dahm, C., W. Kimmerer, J. Korman, P.B. Moyle, G.T. Ruggerone, and C.A. Simenstad. 2019. Developing Biological Goals for the Bay-Delta Plan: Concepts and Ideas from an Independent Scientific Advisory Panel. A final report to the Delta Science Program, Delta Stewardship Council.

Fry, D. H. Jr. 1961. King salmon spawning stocks of the California Central Valley, 1940-1959. California Fish and Game 47(1):55-71.

Hanson, C. H. 2001. Are juvenile Chinook salmon entrained at unscreened diversions in direct proportion to the volume of water diverted? Pp. 331-342 in, R. Brown, Contributions to the biology of Central Valley salmonids. Fish Bulletin 179, vol. 2. California Dept. of Fish and Game, Sacramento.

Healey MC, Angermeier PL, Cummins KW, Dunne T, Kimmerer WJ, Kondolf GM, Moyle PB, Murphy DD, Patten DT, Reed DJ, Spies RB, Twiss RH. 2008. Conceptual models and adaptive management in ecological restoration: the CALFED Bay–Delta Environmental Restoration Program. 40 p.

Healey, M. C., Dettinger, M. D., and Norgaard, R. B. 2008. The state of Bay-Delta science. CALFED Science Program.

Hendrix et al. 2017, Model description for the Sacramento River Winter-Run Chinook salmon life cycle model. Available at https://swfsc.noaa.gov/ChinookLCM/.

Holmes, E. E., E. J. Ward, and M. D. Scheurell. 2014. Analysis of multivariate time-series using the MARSS package, version 3.0. Seattle, WA, USA. Available at https://cran.r-project.org/web/packages/MARSS/vignettes/UserGuide.pdf [accessed 7//4/2018].

Joint Hatchery Review Committee (JHRC). 2001. Final Report on Anadromous Salmonid Fish Hatcheries in California, Review Draft. California Department of Fish and Game and National Marine Fisheries Service Southwest Region.

Miller JA, Gray A, Merz J. 2010. Quantifying the contribution of juvenile migratory phenotypes in a population of Chinook salmon Oncorhynchus tshawytscha. Marine Ecology Progress Series 408:227–240.

Moyle, PB, Israel, JA. 2005. Untested assumptions: effectiveness of screening diversions for conservation of fish populations. Fisheries 30:20-28.

National Oceanic and Atmospheric Administration, National Marine Fisheries Service (NMFS). 2009. Biological and Conference Opinion on the Long-Term Operations of The Central Valley Project And State Water Project (p. 844). Southwest Region.

NMFS. 2014. Recovery Plan for the Evolutionarily Significant Units of Sacramento River Winter-run Chinook Salmon and Central Valley Spring-run Chinook Salmon and the Distinct Population Segment of California Central Valley Steelhead. California Central Valley Area Office.

Nobriga, M. L., Z. Matica, and Z. P. Hymanson. 2004. Evaluating entrainment vulnerability to agricultural irrigation diversions: a comparison among open-water fishes. Pages 281–295 in F. Feyrer, L. R. Brown, R. L. Brown, and J. J. Orsi, editors. Early life history of fishes in the San Francisco estuary and watershed. American Fisheries Society, Symposium 39, Bethesda, Maryland.

Newman, K. B. and D. G. Hankin. 2014. Statistical procedures for detecting the CVPIA natural Chinook salmon production doubling goal and determining sustainability of production increases. Report to CH2M Hill.

Palmer-Zwahlen, M., Gusman, V., and Kormos, B. 2919. Recovery of Coded-Wire Tags from Chinook Salmon in California's Central Valley Escapement, Inland Harvest, and Ocean Harvest in 2014. PFMC and CDFW, Santa Rosa, CA.

Poletto, J. B., D. E. Cochrell, T. D. Mussen, A. Ercan, H. Bandeh, M. L. Kavvas, J.J. Cech, Jr., and N. A. Fangue. Fish protection devices at unscreened water diversions can reduce entrainment: evidence from behavioural laboratory investigations. Conservation Physiology 3:1-12.

U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service (NMFS). 2014. Life Cycle Modeling Framework for Sacramento River Winter-Run Chinook Salmon. Technical Memorandum. Southwest Fisheries Science Center. June.

Williams, J. G. 2006. Central Valley salmon: a perspective on Chinook and steelhead in the Central Valley of California. San Francisco Estuary and Watershed Science 4(3).

Williams, J.G. 2009. Narrative Conceptual Model for Chinook Salmon and Steelhead (Oncorhynchus tshawytscha and O. mykiss) in the Sacramento-San Joaquin Delta. Report for the Delta Regional Ecosystem Restoration Implementation Plan, Sacramento, California.

Williams, J. G. 2012. Juvenile Chinook Salmon (Oncorhynchus tshawytscha) in and around the San Francisco Estuary. San Francisco Estuary and Watershed Science 10(3) [online journal].

Williams, J. G., P. B. Moyle, J. A. Webb, and G. M. Kondolf. 2019. Environmental Flow Assessment: methods and Applications. John Wiley & Sons.

Walters, CJ, Hilborn, R. 1976. Adaptive control of fishing systems. Journal of the Fisheries Research Board of Canada 33:145-159.